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② A method of stripping a resist mask.

② In a downstream ashing apparatus for removing a used organic resist on a silicon semiconductor wafer, according to the present Invention, water vapor is added into an oxygen-plasma gas generated by a microwave power. The addition of the water vapor lowers an activation energy of the ashing reaction, and increases reactive species generated in the plasma, accordingly the ashing rate is increased even at as low as 150 °C of the wafer temperature. The addition of water vapor increases the ashing rate for a wide range of water content, such as from 5 to 80 %, allowing an easy control of the process. The lowered operating temperature prevents contamination of the semiconductor wafer. Nonuse of CF<sub>4</sub> protects the SiO<sub>2</sub> layer from being undesirably etched, resulting in prevention of deteriorating the semiconductor characteristics.

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## A METHOD OF STRIPPING A RESIST MASK

## BACKGROUND OF THE INVENTION

## Description of the Related Art

This invention relates to an improvement of a method of stripping a resist mask, (referred to hereinafter as ashing).

As well known, a mask made of an organic photoresist, etc., is necessarily employed in a photo lithography technique for fabricating semiconductor devices, etc.. After the photoresist is exposed to a light for the photo lithography, the resist must be removed. For removing this used photoresist, a plasma dry etching method, particularly a downstream ashing method, is widely employed. The downstream etching apparatus is such as disclosed by the present inventor in U.S. patent No. 4,512,868 and has been used for processing a silicon wafer, etc., where the wafer is protected from being bombarded by charged particles of the plasma.

The reaction gas used therein for ashing the organic photo resist is, for example, an oxygen gas including a  $\text{CF}_4$  (carbon tetra-fluoride) gas, etc.. However, it is not always easy to remove the used resist. This is because the resist having been affected by its exposure to a light at the exposure process and also its exposure to the plasma in a prior silicon etching process, etc., thus is hardened. Furthermore, the  $\text{CF}_4$  is apt to undesirably etch the silicon wafer. For improving the ashing rate, there is a method in which a nitrogen gas is added to the oxygen containing reaction gas to increase the number of the oxygen atoms, as reaction species. In this method containing 10 % nitrogen for example, the ashing rate is 0.3  $\mu\text{m}/\text{minute}$  at 180 °C, and the increase of the ashing rate achieved with this method is still limited, because the reactive species are mainly the oxygen atoms only, and the function of the above added nitrogen gas is considered to increase only the number of the oxygen atoms as the reactive species. As another way for increasing the number of oxygen atoms, there is known a plasma etching method in which a small amount of water vapor is added to the oxygen plasma gas. However, no extensive study or application gas been carried out, because its beneficial effects have not been appreciated.

## SUMMARY OF THE INVENTION

It is a general object of the invention, therefore 5 to provide an improved ashing method for fast stripping a used resist off a semiconductor wafer.

It is another object of the invention, to lower the activation energy of the reaction, accordingly 10 lowering the reaction temperature.

It is still another object of the invention, to prevent a deterioration of the semiconductor wafer caused by a contamination with metal components 15 contained in the resist.

It is a further object of the invention, to avoid the use of  $\text{CF}_4$  so as to avoid an undesirable etching of silicon wafer during the resist stripping, accordingly to prevent lowering the withstanding voltage of the insulation.

According to the present invention, in a downstream etching apparatus a water vapor is added 20 into an oxygen gas, a reaction gas. The amount of the added water vapor is preferably more than 1 per cent of the total reaction gas by the flow rate.

The addition of the water vapor into the oxygen 25 gas increases reactive species, accordingly the ashing rate, at a wafer processing temperature as low as 150 °C. The lowered ashing temperature prevents contamination of the semiconductor wafer with metal atoms.

The above-mentioned features and advantages 30 of the present invention, together with other objects and advantages, which will become apparent, will be more fully described hereinafter, with reference being made to the accompanying drawings which form a part hereof, wherein like numerals refer to like parts throughout.

## BRIEF DESCRIPTION OF THE DRAWINGS

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FIG. 1 shows effects of water addition in various reaction gases on activation energy.

FIG. 2 shows effects of water addition in an oxygen gas on ashing rate and on number of the atomic oxygen in oxygen plasma according to the present invention.

FIG. 3 shows effects of nitrogen addition in an oxygen gas on ashing rate and on number of the atomic oxygen in prior art gas plasma.

FIG. 4 shows a downstream ashing apparatus for embodying the present invention.

FIG. 5 shows another method for mixing the water vapor into the oxygen gas, for embodying the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring FIG. 1 through FIG. 3, effects of embodying the present invention are presented. An apparatus used for obtaining the data of FIGS. 1 to 3 is schematically illustrated in FIG. 4. This apparatus is commonly used for a downstream ashing, where an microwave power, of typically 2.45 GHz, is fed through a wave guide 1 into a microwave cavity 2. A plasma generating chamber 8 is a part of the cavity 2 and is vacuum-sealed by a quartz plate 2' which is transparent for the microwave power. Reaction gases are fed respectively from outside sources 37 and 38 of oxygen and water, via valves 35 and 36, and flow meters 33 and 34 to the plasma generating chamber 8. Accordingly, a plasma of the reaction gases is generated in the plasma generating chamber 8. On a wall 4, opposite to the quartz plate 2', of the plasma generating chamber 8 there are provided many small holes 41 which connect the plasma generating chamber 8 to a reaction chamber 5 but shield the microwave power. The reaction gas including reactive species, such as oxygen atoms, generated in the plasma flow out of the plasma generating chamber 8 through the holes 41 into the reaction chamber 5 as shown by arrows in FIG. 4. In the reaction chamber 5, a semiconductor wafer 7 to be processed is placed on a stage 6 in a flow of the reaction gas from the holes 41, so that the reactive species reacts with the resist on the semiconductor wafer 7. Temperature of the stage 6 is raised and controlled by a heater 61 installed in the stage. The reaction gas in the reaction chamber 5 is evacuated by a pump (not shown in the figure) through an outlet 51.

As for the ashing process procedure, the wafer 7 on the stage is once heated up as high as approximately 200 °C while the chamber 5 is evacuated to approximately 0.01 Torr by the pump. Next, the inner pressure of the reaction chamber 5 is raised up to approximately 0.8 Torr and the approximately 1.5 kW microwave power is applied to the plasma generating chamber 6 so as to generate a gas plasma therein.

FIG. 1 shows effects of adding water, nitrogen or hydrogen to an oxygen gas, measured by their flow rate ratio, on activation energy. From FIG. 1 it is observed that the activation energy is lowered from approximately 0.5 eV to approximately 0.4 eV by adding hydrogen or water; however, no effect is observed by adding nitrogen. On the other hand, as well known, a speed constant  $k$  of a chemical reaction is generally given by the following formulae Arrhenius' equation:

$$k = A \exp(-E/RT)$$

where  $A$  indicates a frequency factor,  $E$  indicates an activation energy,  $R$  indicates a gas constant and  $T$  indicates the absolute temperature. Therefore, lowered value of the activation energy means a faster reaction at a certain temperature, in other word, a certain reaction speed achieved at a lower temperature.

Effects of adding water were observed by the inventors, and are shown in FIG. 2, for which a 1,000 cm/min reaction gas flow, including oxygen gas added with water vapor and 50 cm/min of argon gas are used in the apparatus shown in FIG. 4, keeping the water temperature at 180 °C. Percentage of the water vapor content,  $H_2O/C_2 + H_2O$ , is measured by their flow rate. The argon gas, which has no effect on the ashing reaction, is added thereto just for generating a standard light spectrum with which oxygen atoms, etc., can be quantitatively compared by an actinometry technique, which is as reported by J.W. Coburn et al. on Journal Applied Physics, vol. 51, No. 6, 1980, pp. 3134. A glass fiber 9 is installed on the wall of the cavity 2 to watch the lights generated in the plasma through the transparent quartz plate 7, which is also optically transparent. Another end of the glass fiber 9 is connected to a monochromator 10. In FIG. 2, black dots show the ashing rate scaled by the right hand side vertical axis, and white dots show the relative oxygen atom concentration scaled by the left hand side vertical axis. The relative oxygen atom concentration is measured by an actinometry method, i.e. by the ratio of the intensity of 6158 Å oxygen atom spectrum to the intensity of 7067 Å argon spectrum.

It is observed in FIG. 2 that an addition of approximately 10 % to 60 % of water vapor almost doubles the ashing rate of the case where no water is added, and the ashing rate completely relates to the amount of the oxygen atom concentration. However, at the range over 50 % of water content, the ashing rate curve slowly falls but the oxygen atom concentration curve falls faster than the ashing rate curve. This separation of the oxygen atom concentration curve from the ashing rate curve suggests that another reactive species, such as OH (hydroxide) radical, etc., are also contributing to the ashing reaction. For comparison, an effect of the nitrogen addition to an oxygen is shown in FIG. 3, for which the total gas flow and the temperature are the same as those of FIG. 2. In FIG. 3, the black and white dots respectively show the same as in FIG. 2, and the triangle dots show a relative concentration of the oxygen atoms measured by 4368 Å oxygen atom spectrum. In either of FIG. 2 and FIG. 3, the ashing rates are almost the same, i.e. 0.3 μm/minutes, at 180 °C. However, as the effect of the lowered activation energy, the ashing rate of 40 % water-containing oxygen achieves

0.15  $\mu\text{m}/\text{minute}$  is achieved at as low as  $150^\circ\text{C}$ , compared with  $0.1 \mu\text{m}/\text{minute}$  of an 10 % nitrogen-containing oxygen which is optimum for the fastest ashing rate, at the same temperature. These data are not shown in a figure. The lowered temperature for the ashing is significantly advantageous in that the semiconductor wafer is protected from a contamination of the metal components included in the resist material. As well known, the metal contamination deteriorates the semiconductor properties, such as heavy metals lower the minority carrier generation life time, and alkaline metals also contaminate the semiconductors.

As seen in FIG. 2, the curve of the ashing rate of the water-containing oxygen is relatively flat over the wide range of the water content, i.e. from 10 % to 80 % approximately, and is much wider than the range 5 to 15 % of the nitrogen-containing oxygen as shown in FIG. 3. This is advantageous for an easy control of an ashing operation at a production stage.

The beneficial advantage of avoiding the use of  $\text{CF}_4$  is as follows: When a 10 %  $\text{CF}_4$ -containing oxygen gas is used for the resist etching in a downstream apparatus, the  $\text{SiO}_2$  layer on the semiconductor wafer is also etched undesirably. The ratio of the resist ashing rate to the  $\text{SiO}_2$  etching rate, i.e. the selectivity, is typically 300 to 500. That is to say, while 1  $\mu\text{m}$  of the resist is ashed, the  $\text{SiO}_2$  is etched 30  $\text{\AA}$ , for example. This undesirable etching of the underlying  $\text{SiO}_2$  layer used for a gate insulation lowers the withstanding voltage of the gate insulation, or deteriorates electrical characteristics of the semiconductor circuits. There is the same problem with polycrystalline silicon,  $\text{SiN}$ , or aluminum, as well. This problem has not been so serious in fabrication of conventional relatively low-density LSI (large scale integrated circuit), because the insulation layer is as thick as 1000  $\text{\AA}$  for 16 K bit memory devices. However, this problem is now becoming serious for fabricating the most up-to-date 1 M bit memory devices, because the insulation layer is as thin as 200  $\text{\AA}$  or less. According to the method of the present invention, there is no longer the undesirable etching problem of the  $\text{SiO}_2$  layer, etc., at all.

As described above, in the downstream ashing apparatus the gas plasma, i.e. the electromagnetic power to generate the plasma, is confined in the plasma generating chamber by a shielding wall, only the reactive species generated in the plasma come out via many small holes on the shielding wall. The holes shield the electromagnetic waves but allow the reactive species to pass therethrough to react with the resist material. Therefore, the wafer is protected from a bombardment of the charged particles, such as ions, which may cause the deterioration of the semiconductor materials.

Therefore, the reaction is purely chemical. The above-described beneficial effects of adding the water vapor in an oxygen gas can be significantly enhanced by being combined with the beneficial effect of the downstream apparatus, and is highly appreciated in the production of VLSI (very large scale integrated circuit) such as of submicron integration.

Typical and preferable methods of adding the water vapor to the oxygen gas are schematically illustrated in FIG. 4 and 5, where the same or equivalent parts are denoted with the same numbers of those of FIG. 4. In the apparatus of FIG. 4, the plasma generating chamber 8 is provided with two gas inlets 31 and 32, for introducing oxygen gas and water vapor respectively and independently from each other. Each gas is supplied to the inlet 31 and 32 from each gas source 37 and 38 through a control valves 35 and 36 and flow meters 33 and 34, respectively. If the gases are to be fed into the plasma generating chamber 8 through a single inlet, the amount of mixing the water vapor into the oxygen gas is influenced by the amount of the oxygen gas flow and the fluid resistance of the inlet pipe between the place of the water vapor mixing to the chamber 8. Therefore, in such an apparatus, it is not easy to control to add a large amount of the water vapor, such as more than 10 %, because of the relatively high gas pressure of the oxygen gas caused by the above mentioned fluid resistance. However, this problem can be solved in the apparatus shown in FIG. 4.

In the apparatus of FIG. 5, the water vapor is mixed into the oxygen flow while the oxygen gas is flowing, in other words, bubbling through a heated water 39 on the way from the gas source 37 to the chamber 8. The amount of the added water vapor is determined by the balance of the vapor pressure of the water 39 at its present temperature and the pressure of the oxygen. The water vapor pressure can be raised and controlled by the temperature of the water through which the oxygen gas is flowing. The water temperature is controlled by the heater 40. Because of relatively high vapor pressure of the heated water, a considerable amount, such as more than 10 %, of the water vapor can be easily mixed into the oxygen gas, under precise control.

As shown in FIG. 1 an addition of a hydrogen gas into an oxygen gas exhibits a good effect to lower the activation energy. However, as is well known, the mixture of more than 3 % hydrogen gas in the oxygen gas will cause an explosion. Therefore, the hydrogen gas can not be industrially employed as the plasma reaction gas.

The many features and advantages of the invention are apparent from the detailed specification and thus, it is intended by the appended claims to cover all such features and advantages of the

method which fall within the true spirit and scope of the invention. Further, since numerous modifications and changes may readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.

essentially shield said semiconductor wafer from said electromagnetic power, whereby said reactive species reacts with the used organic resist to be removed; and

5 a gas outlet (51) operatively connected to said reaction chamber for evacuating said reaction chamber.

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## Claims

1. An ashing method for removing a used organic resist from a semiconductor wafer, comprising:

15 generating a gas plasma of an oxygen gas containing water vapor by applying an electromagnetic power to a plasma generating chamber; and  
Introducing reactive species generated in said gas plasma from said plasma generating chamber via holes of a chamber wall toward the semiconductor wafer to react with the used organic resist; said wall and said holes essentially shielding said semiconductor wafer from said electromagnetic power.

2. An ashing method for removing a used organic resist according to claim 1, wherein the contents of said water vapor is more than 1 % of the total gas by flow rate.

3. An ashing method for removing a used organic resist according to claim 1 or 2, wherein said electromagnetic power is a microwave power.

4. An ashing method for removing a used organic resist according to claim 3, where said microwave power is of essentially 2.45 MHz.

5. A plasma ashing apparatus for removing a used organic resist on an semiconductor wafer, comprising:

a plasma generation chamber (8) for generating a plasma of a reaction gas including an oxygen gas and a water vapor, said plasma being generated by an excitation of an electromagnetic power applied into said plasma generation chamber;

40 a first gas inlet (31), operatively connected to said plasma generating chamber, for feeding other part of said reaction gas than said water vapor into said plasma generating chamber;

a second gas inlet (32), operatively connected to

said plasma generating chamber, for feeding said water vapor into said plasma generating chamber;

45 a flow control means (38) for regulating a flow of said water vapor into said plasma generating chamber;

a reaction chamber (5) for placing a semiconductor wafer (7) therein, said reaction chamber being separated by a wall (2) from said plasma generating

50 chamber, said wall having holes (41) on said wall for supplying a reactive species generated in said plasma into said reaction chamber, said holes es-

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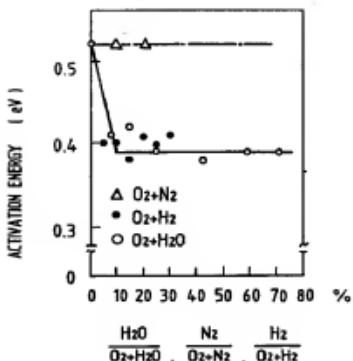


FIG. 1

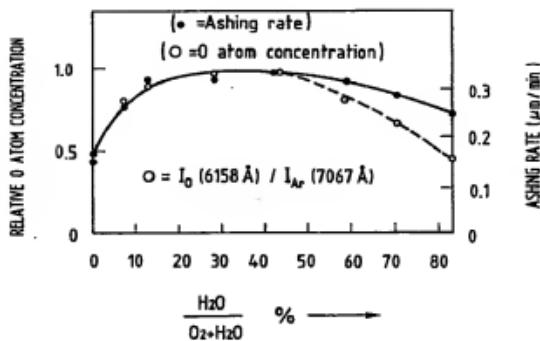


FIG. 2

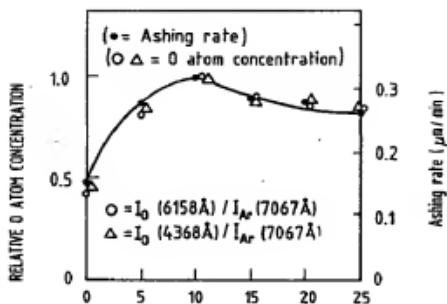


FIG. 3

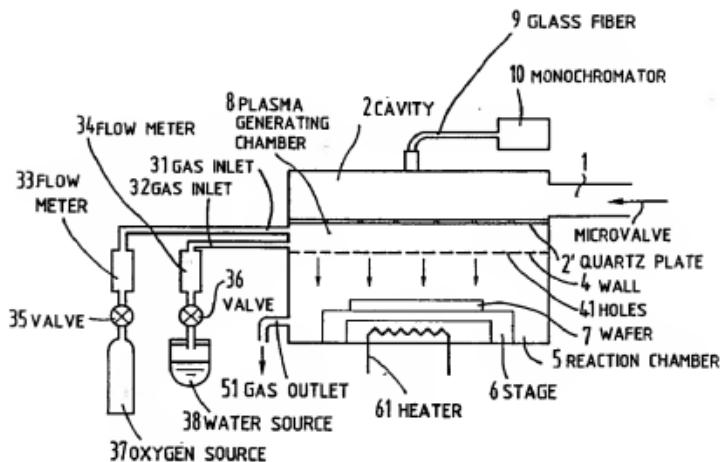
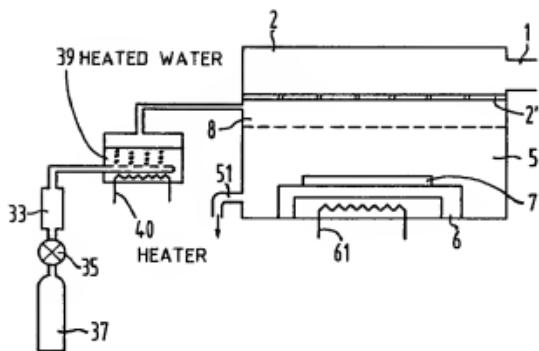


FIG. 4



**FIG. 5**



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② A method for stripping a photo resist on an aluminium alloy.

② An interconnection pattern made of aluminium alloy, such as Al-Cu, on a semiconductor IC is dry-etched in an etching gas. When an etching gas containing chlorine is used, residual chlorine on the substrate is difficult to remove, and causes corrosion of the patterned aluminium alloy layer. According to the present invention, the photo resist stripping process following the etching process is carried out by a downstream stripping process using a conventional etching gas, such as CF<sub>4</sub> + O<sub>2</sub>, at room temperature, and, before the resist-stripped substrate is exposed to the atmosphere, the substrate is heated in a vacuum at higher than 100°C, thus the residual chlorine component is removed. The heating process can be carried out concurrently during the resist stripping process. By this means corrosion of the aluminium alloy interconnection is prevented.

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## A method for stripping a photo resist on an aluminum alloy.

This invention relates to a method for stripping a photo resist coated on a layer of an aluminum alloy, such as aluminum-copper, formed on a semiconductor substrate.

Aluminum or aluminum-silicon alloy containing several percent of silicon has been generally used for an interconnection layer on a semiconductor device. However, it is also well known that the interconnection layer may be broken by electromigration, particularly in a semiconductor device where a very fine interconnection is required, such as 4  $\mu$ m for a high speed ECL (Emitter Coupled Logic) or 1  $\mu$ m for MOS (Metal Oxide Semiconductor), to achieve a greater density of integration, and a correspondingly higher density of the current flowing therethrough is required. In order to prevent this electromigration of the interconnection layer, an aluminum-copper alloy containing 2 to 4% of copper has come to be used, particularly where a high current-density is handled as in a bipolar device or a high-speed logic circuit. However, the aluminum-copper alloy suffers from problems due to residual chlorine therein.

When an aluminum or aluminum alloy layer is plasma dry-etched by chlorinated gases, such as a mixture of chlorine (referred to hereinafter as Cl<sub>x</sub>) with silicon tetrachloride (SiCl<sub>4</sub>) or boron trichloride (BCl<sub>3</sub>), the residual chlorine problem arises as follows:



where Cl<sup>·</sup> denotes a chlorine radical produced in the plasma, and t denotes sublimation. The aluminum, Al, reacts with Cl<sup>·</sup> to produce AlCl<sub>3</sub> or Al<sub>2</sub>Cl<sub>5</sub>, which then sublimes, and the aluminum continues to be etched in this way. When the etch-processed substrate is brought out into the open air, the AlCl<sub>3</sub>, etc., which has sublimed and deposited on a surface of the side wall of the aluminum layer or on a photo resist reacts with atmospheric water, because the AlCl<sub>3</sub> is deliquescent. Hydrochloric acid (HCl) is thus produced thereon as shown by the following equation:



The HCl then reacts with the Al to produce AlCl<sub>3</sub> again as follows:



25 Thus, the reactions are continued repeatedly. In other words, the corrosion of the aluminum layer continues indefinitely. In order to prevent this corrosion, one or more of the following procedures is or are carried out for aluminum, aluminum-titanium (Al-Ti) alloy or aluminum-silicon (Al-Si) alloy, after the dry etching process:

(1) Stripping the photo resist without exposing the substrate to the open air so as to prevent the chlorine deposit on the substrate from reacting with the water content in the open air.

(2) Drying the substrate with a hot nitrogen gas blast at up to 100 to 200°C, and then washing it with water so as to remove the residual chlorine.

(3) Washing the substrate with water, and then baking it in an oxygen atmosphere at approximately 350°C so as to remove the residual chlorine.

35 (4) Plasma-processing the substrate in a fluorinated gas, such as CF<sub>4</sub>, SF<sub>6</sub> or CHF<sub>3</sub>, so as to replace the residual chlorine atoms by the fluorine atoms produced in the plasma. A stable aluminum fluoride (AlF<sub>3</sub> or AlF<sub>5</sub>) is thus formed over the aluminum surface to prevent the chlorine component from reacting with water contained in the air.

(5) Plasma-processing the substrate in hydrogen gas, which reacts with the residual chlorine component to produce hydrogen chloride.

40 By the application of the above-mentioned procedures the residual chlorine component on the substrate made of the above-mentioned aluminum or aluminum alloys can be removed, and thus the corrosion can be prevented. However, when an aluminum alloy, such as aluminum-copper (Al-Cu) or aluminum-copper-silicon (Al-Cu-Si) is etched, its chlorine component remains in the form of Cu<sub>2</sub>Cl<sub>4</sub> or a mixture of Cu, Cl, Al and carbon from the photo resist, which are difficult to remove as they have much higher sublimation temperatures than aluminum chloride, and may therefore cause corrosion even after the above-described chlorine-removal processing is carried out.

To overcome the above-mentioned problems an improved method of removing the residual chlorine is desirable.

45 It is an object of the invention to provide a method that may be used to form a pattern of an aluminum alloy on a semiconductor substrate without corrosion problems caused by residual chlorine on the substrate.

According to the invention, a method for etching an aluminum alloy pattern on a semiconductor substrate comprises the steps of:

- forming a layer of aluminum alloy on a semiconductor substrate having an insulation layer thereon;
- forming a resist pattern on said aluminum alloy layer;
- etching an exposed portion of said aluminum alloy layer by the use of said resist pattern as a mask, whereby said aluminum alloy layer is patterned;
- stripping said resist pattern in an atmosphere containing a reactive species; and
- heating the substrate in a vacuum at a temperature higher than 100°C, whereby residual etching agent on the substrate is removed, said heating step being carried out concurrently with said stripping step or after said stripping step.

In an embodiment of the invention, the method includes the steps of: forming a layer of aluminum-copper alloy on a semiconductor substrate; forming a resist pattern on said alloy layer; etching said alloy layer by the use of said resist pattern in a chlorinated gas plasma so as to form an alloy pattern; downstream stripping said resist pattern in an atmosphere containing a reactive species; and heating the thus-processed substrate in a vacuum at a temperature higher than 100°C, to remove the residual chlorine component. The stripping process and the heating process may be combined; that is to say, be carried out concurrently.

The above-mentioned features and advantages of the present invention, together with other objects and advantages, which will become apparent, will be more fully described hereinafter with reference to the accompanying drawings, in which like numerals refer to like parts throughout.

Figs. 1(a) to 1(d) are sectional views that schematically illustrate the main part of a semiconductor device at successive steps of a fabrication process according to the present invention.

Fig. 2 schematically illustrates a dry processing apparatus using microwave power, used for the stripping step of the present invention.

Referring now to Figs. 1(a) to 1(d), the fabrication steps in a preferred embodiment of the present invention are as follows:

By general fabrication methods (not shown in the Figures) a semiconductor substrate 1 is fabricated with IC devices thereon and coated with an insulation film thereon, for example of PSi (phospho silicate glass). A layer 2 of an aluminum-copper alloy, for example Al-Cu(4%) up to approximately 8000Å thick is formed all over the semiconductor substrate 1 by a known general method, such as sputtering, as shown in Fig. 1(a). A photo resist film is formed upon the alloy layer 2, and the resist film is patterned, as denoted by 3 in Fig. 1(b), by a known general lithography technique. The exposed portion of the alloy layer 2, i.e. the portion not masked by the photo resist pattern 3, is removed by a known general dry etching method. The dry etching may be a reactive ion etching method using an etching agent an etching gas such as a mixture of chlorine (Cl<sub>2</sub>) gas (24 sccm (standard cubic centimeter per minute)) and silicon tetrachloride (SiCl<sub>4</sub>) gas (40 sccm). The gas pressure is reduced to approximately 0.02 Torr (2.67 Pa), and radio frequency power of 13.56 MHz, for example, and 250 W, for example, is applied thereto for 5 minutes, for example, by well known methods. The etching gas is dissociated in a glow discharge driven by the applied radio frequency power and the chlorine atoms produced are active to react with the aluminum as well as the copper of the alloy. The aluminum chloride sublimes in the same manner as explained in the description of the prior art, and the copper chloride is sputtered by the energetic ion bombardment, so that the exposed portion of the alloy is etched and removed leaving the patterned layer 2, as shown in Fig. 1(c). Next, the substrate 1 is transferred to a dry processing apparatus for stripping the patterned photo resist 3, passing through a vacuum system or an inert gas purged system, in order to avoid being exposed to the atmosphere. If the substrate is exposed to the atmosphere, the residual chlorine on the substrate reacts with water contained in the air and corrodes the alloy, as explained in the prior art.

The patterned photo resist 3 on the patterned alloy layer 2 is then stripped by a known downstream etching method. A stripping apparatus using microwave power, which is preferably employed in this stripping step, and is also called a downstream ashing or an after-glow ashing, will be described in detail later. As a reaction gas in the dry etching, a mixture of a Cl<sub>2</sub> gas (100 sccm) and oxygen (O<sub>2</sub>) gas (1500 sccm), for example, is used at approximately 1 Torr (1.33 x 10<sup>2</sup> Pa), and microwave power of 2.45 GHz and 1 KW is applied thereto for 2 minutes, for example, while the substrate is kept at room temperature, such as 30°C. After finishing this stripping process, the substrate is heated so that the residual chlorine component is baked out. In the apparatus shown in Fig. 2 the heating is effected by the electric heater 31 built in the stage 25 to approximately 300°C for 2 minutes for example while the apparatus is pumped out to 0.2-0.3

Torr (0.27-0.4 x 10<sup>2</sup> Pa). After the substrate is cooled enough, the substrate is brought out of the apparatus, thus the processes of the invention are all finished. This method will be referred to as method I. It is also possible to heat the substrate on a separate heating stage from the stripping stage 25 in the vacuum chamber in order to save the cycle time for heating/cooling the massive stage.

5 The last baking process of method I may be combined with the stripping process. In other words, these two processes can be carried out concurrently. In this case, the stripping process is carried out while the substrate 1 is heated to 200 to 300°C by an electric heater 31 mounted in the stage 25. This method will be referred to as method II.

When the stripping and baking processes are combined as in method II, the etching gas may be a mixture of nitrogen (N<sub>2</sub>) gas (100 sccm) and oxygen (O<sub>2</sub>) gas (1500 sccm) at approximately 1 Torr (1.33 x 10<sup>-2</sup> Pa), and the substrate may be heated at 200 to 300°C. This method will be referred to as method III.

In these methods, the combination of the heating and the downstream stripping is essential, because heating without stripping cannot remove the residual chlorine components under 400°C. Moreover, conventional plasma stripping causes a particle problem by Al<sub>2</sub>O<sub>5</sub> formation.

10 In order to confirm the effect of the above-described methods of the present invention, the processed substrate was exposed to the atmosphere for 2 days. The alloy pattern was then optically observed to check for corrosion, and the residual chlorine atoms were measured by X-ray fluorescence spectroscopy. The check results are set out in the following table, in which

- (a) shows the temperature of the substrate during the heating, in °C,
- 15 (b) shows existence of the corrosion found by optical observation using a microscope of magnification x 1000, and
- (c) shows the amount of residual chlorine atoms in units of cps (counts per second), where 10-cps corresponds to 1.84 x 10<sup>4</sup> atoms per cm<sup>2</sup>.

	Method	I	II	II	II	II	II	III
25	(a)	300	30	70	110	150	200	300
20	(b)	no	yes	yes	no	no	no	no
25	(c)	8.1	141.1	122.2	21.4	11.6	9.5	8.3

As seen in the Table, when the substrate is heated at above 100°C, the residual chlorine is evidently reduced and no corrosion is observed. The amount of residual chlorine is reduced as the heating temperature is raised, but on the other hand, if the temperature exceeds 300°C, the aluminum is affected: for example hillocks are formed on the surface of the aluminum. Therefore, the temperature must be lower than 400°C, and preferably be chosen between 250 and 300°C.

An embodiment of the dry etching apparatus for stripping the photo resist will now be described in detail, with reference to Fig. 2. The apparatus employs microwave power for producing reactive species as etching agent. The substrate 1 is loaded on the stage 25 in a reaction chamber 30. In the stage 25, an electric heater 31 and a thermometer (not shown in the Figure) are mounted to heat the substrate when required. The chamber 30 is evacuated through gas outlets 29 by conventional evacuation equipment, which is not shown in the Figure. An etching gas is introduced into the chamber 30 through the gas inlet 27. By balancing the gas evacuation and gas introduction, the gas pressure within the chamber 30 is controlled to obtain the required gas pressure. A microwave-passing window 23 made of an insulating material, such as quartz or alumina, is installed perpendicularly to the electric field in the wave guide 21 and also seals the vacuum of the chamber 30. A metal shield plate 28 having many small holes therein shields the microwaves from the reaction chamber 30, so that a plasma generation chamber 29 is formed between the microwave-passing window 23 and the shield plate 28. Microwave power 22 is fed through the wave guide 21 and through the microwave-passing window 23 into the plasma generation chamber 29. In the plasma generation chamber 29, the etching gas is made into plasma by the excitation by the microwave power. A reactive species, such as oxygen atoms, produced in the plasma comes out through the holes of the shield plate 28 and flows directly down on to the substrate 1, i.e. efficiently, because the shield plate 28 is located close to the substrate 1. This reactive species is very reactive with the photo resist on the substrate, but does not harm the substrate by an ionic bombardment as in the plasma etching because the species coming out of the holes of the shield plate 28 is not ionic and no other ionic gas comes out at all. Therefore, this type of apparatus is advantageously employed for stripping the photo resist.

Although aluminum-copper alloy is referred to in the above-described embodiment as the material to be processed, the present invention is also effective for other alloys such as AlCuSi and AlSiTiCu.

Although a mixture of  $Cl_2$  and  $SiCl_4$  is referred to as an etching gas for etching the alloy in the above-described embodiment, other gases of chlorine family, such as  $BCl_3$ ,  $CCl_4$  and  $CHCl_3$ , can be also used therein, as is well known.

Although a dry etching apparatus using a radio frequency of 13.56 MHz is referred to in the above-described embodiment for etching the alloy, other types of dry etching apparatus, for example using a radio frequency of 400 kHz, can also be used, as is well known.

Although a mixture of  $CF_4$ ,  $N_2$  and  $O_2$  is referred to as an etching gas for stripping the photo resist in the above-described embodiment, other fluorinated gases, such as  $CHF_3$ ,  $CF_3Cl$ ,  $SF_6$ ,  $NF_3$  or  $CBiF_6$ , can be also used, singly or mixed, in place of  $CF_4$ , and other nitrogen-containing gases, such as  $N_2O$  or  $NO_2$ , can be also used in place of  $N_2$ , as is well known.

Although a dry etching apparatus using a microwave frequency of 2.45 GHz is referred to in the above-described embodiment for stripping the photo resist, other types of dry etching apparatus, e.g. using a radio frequency of 13.56 MHz, can also be used, as is well known.

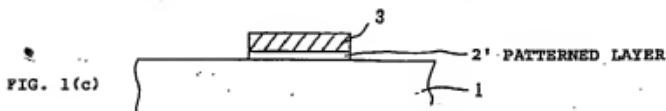
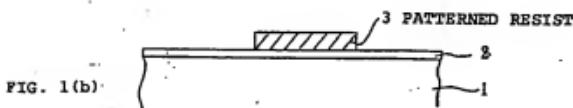
The many features and advantages of the invention are apparent from the detailed specification. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention as claimed.

20 **Claims**

1. A method for etching an aluminum alloy pattern on a semiconductor substrate, comprising the steps of:  
25 forming a layer of aluminum alloy on a semiconductor substrate having an insulation layer thereon; forming a resist pattern on said aluminum alloy layer; etching an exposed portion of said aluminum alloy layer by the use of said resist pattern as a mask, whereby said aluminum alloy layer is patterned; stripping said resist pattern in an atmosphere containing a reactive species; and heating the substrate in a 30 vacuum at a temperature higher than 100°C, whereby residual etching agent on the substrate is removed, said heating step being carried out concurrently with said stripping step or after said stripping step.  
2. A method according to claim 1 wherein said etching is carried out by a dry etching method.  
3. A method according to claim 2 wherein said dry etching is carried out by the use of a gas containing chlorine.  
4. A method according to claim 3 wherein said gas is chosen from the group of chlorine gas, silicon 35 tetrachloride gas, boron trichloride gas, and carbon tetrachloride gas.  
5. A method according to any preceding claim wherein the temperature in said heating step is lower than approximately 400°C.  
6. A method according to any preceding claim, wherein said reactive species are produced from a 40 mixture of a fluorinated gas and oxygen gas.  
7. A method according to any one of claims 1 to 5, wherein said reactive species are produced from a mixture of a nitrogen-containing gas and oxygen gas.  
8. A method according to any preceding claim, wherein said reactive species is produced by excitation by microwave power of approximately 2.45 GHz.  
45 9. A method according to any preceding claim wherein said aluminum alloy is an aluminum-copper alloy.

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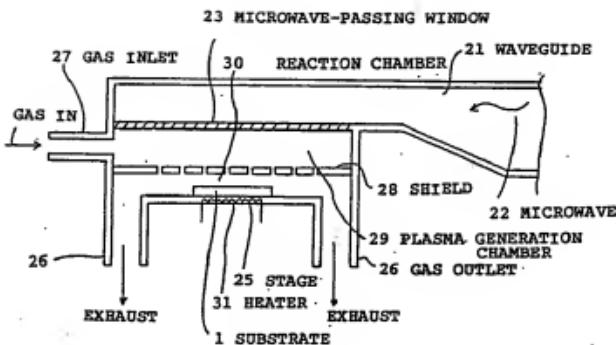


FIG. 2